A Ph.D. SYNOPSIS
In the area of
Power Quality
On the topic

Power quality issues in grid connected solar power system

Submitted by

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1. INTRODUCTION

1.1 General

Due to modernization of human society the demand for electrical energy has increased exponentially. **R**enewable-Energy sources such as solar and wind energy systems seems to be the most promising and attractive solutions and gaining more attention both in research and industrial communities. In tropical countries like India especially during summers solar powered system could be a good solution to reduce the dependence on conventional fossil fuel systems and can meet the requirement during critical situation. Solar panel research and development was documented in the 18th century by Charles Fritts. Almost a century later, a Silver-Selenide version was constructed by Bruno Lange at 1% efficiency. Later, in the 1940s with more research invested in solar technology, efficiencies of 4.5-6% were achieved at 286 USD/watt [1].Further, investments into research and development of solar electric cells brought this technology to a commercial level with prices of 2.49 USD/watt. According to [2] solar modules in the market today are priced below $2.00 per watt. Solar generating systems are proliferating at every level, whether residential, commercial or utility-scale. The challenges faced by engineers and researchers are more in integrating PV systems to the grid system than dealing with the advancement in core technology.

Over the past decade, power quality (PQ) issues means both voltage quality and current quality have become increasingly important in the grid connected PV generation system especially due to the widespread use of non-linear electronic equipment. The most cited PQ problem that may arise in any grid connected PV generation system (shown in Fig-1) is the deviation of voltage or current from the ideal (sinusoidal) waveform.(i.e.) It may be a voltage disturbance or a current disturbance are voltage dips and fluctuations, harmonic distortion, transient phenomena and reverse power flow which result in potential damaging of sensitive electronic equipment and capacitor banks, overheating of transformers and neutral conductors and additional losses in the power system[3] [4]. It should be noted here that a voltage disturbance originates from the grid and while a current disturbance originates from a customer or device which finally affects the network and/or other customers or devices or equipment.

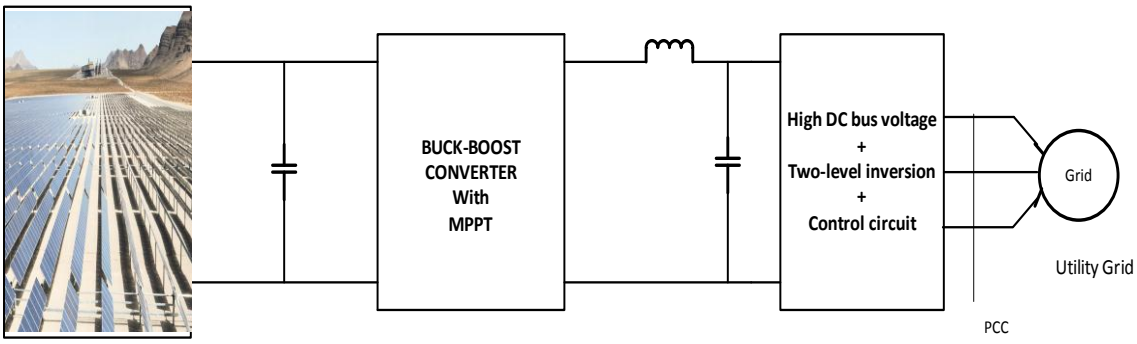

Figure-1: Grid connected PV generation system

Electrical motors constitute more than 40% of total Electrical power [5].Traditionally, PV array powered DC-motor drive systems have been used to supply electric power to motors in irrigation or ventilation systems but later on PV array powered Induction motor drive systems found to be more reliable, maintenance-free, less expensive and they do not have the comutator and brushes apart from all the advantages mentioned Induction motor has two main disadvantages, one the efficiency is not as high as dc motor, second it requires PV system with two power conditioning stage as shown in Fig. 2 which results in poor performance, less efficiency and finally distortion of system bus voltage. Degraded power quality entails additional costs for both the electricity distributor and its customers

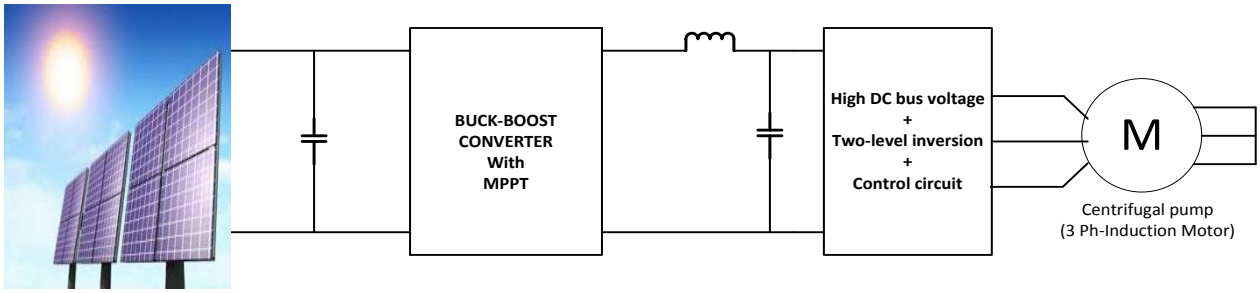

Figure-2: Block diagram of Conventional two stages PV-powered centrifugal pump.

2. Literature Review

An extensive study is done in various topics of solar generating system and the references are listed in different categories as papers on survey and review [6-20], papers on inverter topologies and applications [22-37], papers on induction motor drives and control [38-50], papers on Neural networks [51-60], papers on optimization and soft computing [61-68] and Papers on power quality [69-80], lastly text books/Magazines [81-94].

2.1Multi-level inverters

Multilevel inverters have been used widely because of their high power capability, lower output harmonics and lower commutation losses etc. Multilevel inverters have the main advantages that the harmonic components of line-to-line voltage fed to load, switching frequency of the devices and electromagnetic interface (EMI) problem could be decreased. They can also reduce the stress on the switching devices as higher levels are synthesized from voltage sources with lower levels. These features have made them suitable for application in large and medium induction motor drives. For decades extensive review and survey on Topologies, Control, focus on renewable energy and industrial applications of multilevel inverters were presented by researches in various journal, magazines and conferences [1]-[18]. In recent years, many multilevel inverters synthesizing a large number of levels have been presented [19]–[38].Nowadays, there exist five different topologies of multilevel voltage-source inverters

1. Diode-Clamped Inverter or (NPC)
2. Capacitor-Clamped Inverter or Flying capacitor(FCs)
3. Cascaded Multicell Inverters or (CHB)
4. Generalized multilevel Cells
5. Open-end winding induction motor fed by dual inverters [34]-[39]

The first three are commercially available in the market and among these inverter topologies, cascaded multilevel inverter reaches the higher output voltage and power levels (13.8 kV, 30 MVA) and higher reliability due to its modular topology.

2.2 Different control strategies

The modulation methods used in Multi-level inverters can be classified according to switching frequency. The few important strategies are

i. Multilevel SPWM
ii. Space vector modulation (SVM)
iii. Selective Harmonic Elimination (SHE)

iv. Space vector Theory (SVC)

v. Direct- Torque Control (DTC)

vi. Vector Control Method

vii. Capacitor Balancing Techniques

The various applications of multilevel inverters can be broadly classified as

Pumps and Fans, STATCOM, Traction, LNG Plant, Industrial drives,Applications in power system and PV Modules

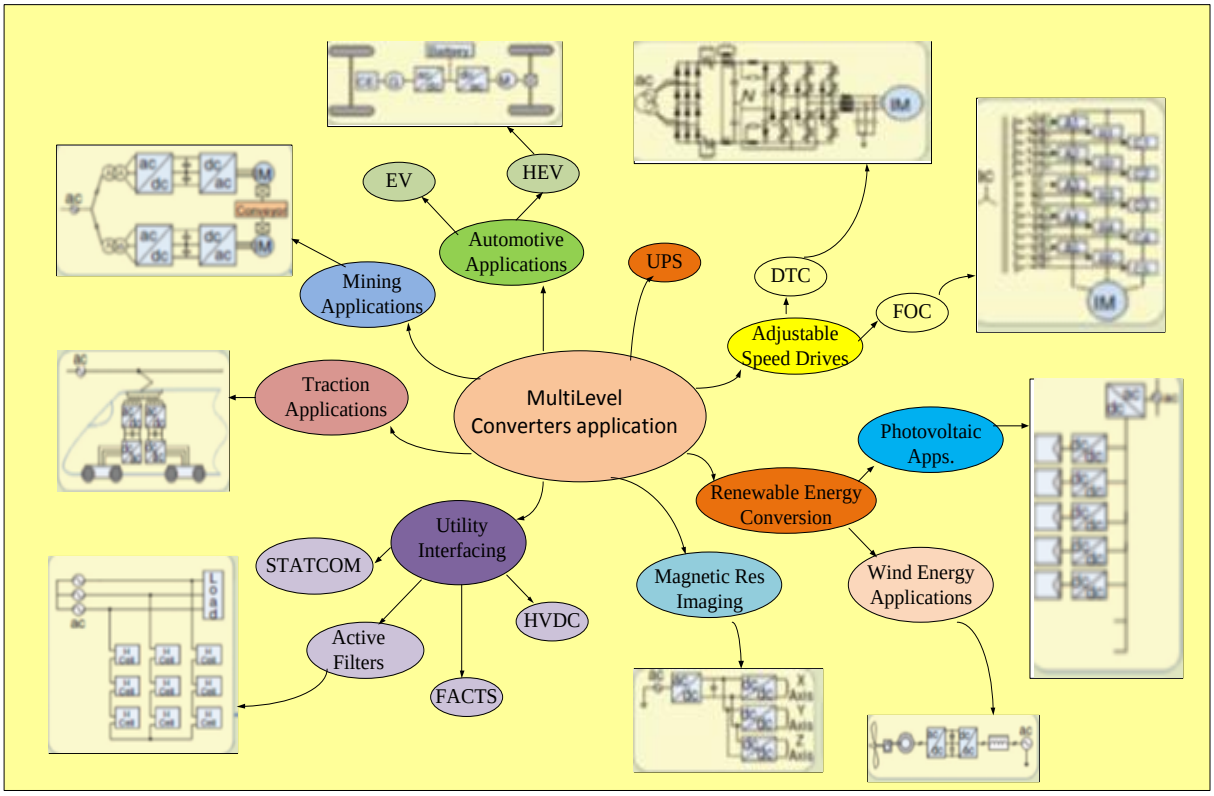

Figure-3: — Multilevel converter-driven applications overview[5].

By looking at fig-3 and the number of papers published in recent years, it is easy to conclude that multilevel inverter research and its application are experiencing an explosive rate of growth. A trend of having more and more multilevel inverters is obvious with reduced number of devices and also its applications for various new technologies.

2.3 Selective Harmonics Elimination

Among various methods of Pulse Width Modulation (PWM) techniques mentioned in the literature Selective Harmonic Elimination (SHE) pulse width modulation has its own advantages in modern power electronics applications especially for inverter/converter circuits. The Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM) is widely used in UPS, reactive power compensators and power filters as this provides the highest quality output among all the PWM methods. The physical model of SHE-PWM

technique is easy to realize because of which this method has become very popular among all the control signal generation technique. In spite of all the advantages mentioned above, it is very difficult and complex to obtain the desired solutions from a non-linear transcendental equation which contains trigonometric terms that exhibit multiple solutions naturally. Many tools and algorithms [18, 32, 35, and78] have been proposed which led to feasible implementation of SHE-PWM techniques for various applications; all these techniques are very complex and time consuming.

There is a need to develop a simple method to solve nonlinear equations of SHE-PWM, which is less complex, less time consuming and capable of giving results with higher accuracy. For this problem soft computing techniques may be applied to get solutions of nonlinear equations of SHE-PWM

2.4 Soft computing Techniques

2.4.1 Neural networks(NNW)

A NNW consists of a number of artificial neurons that are interconnected together. The structure of artificial neuron is inspired by the concept of biological neuron shown in Fig.4(a).

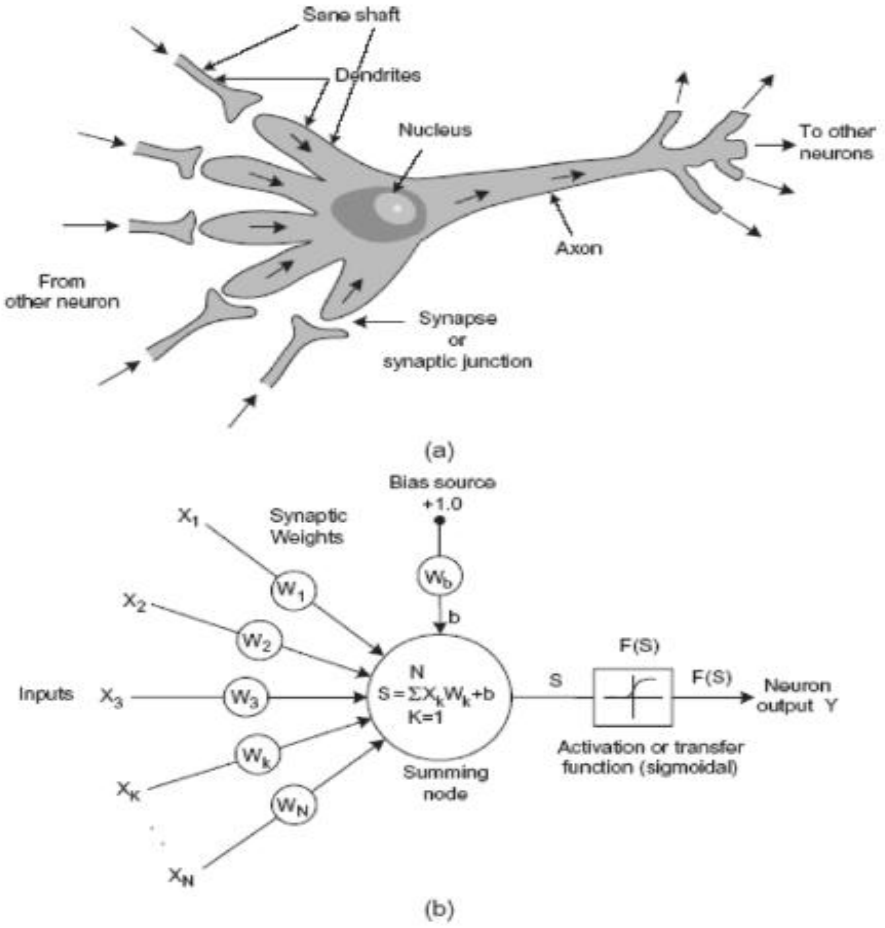

Figure.4. (a) Structure of biological neuron. (b) Model of artificial neuron [58]

A few NNW models can be listed from the literature [52-61] as follows.

1) Perceptron

2) Adaline and Madaline

3) Backpropagation (BP) Network

4) Radial Basis Function Network (RBFN)

5) Modular Neural Network (MNN)

6) Learning Vector Quantization (LVQ) Network

7) Fuzzy Neural Network (FNN)

8) Kohonen's Self-Organizing Feature Map (SOFM)

9) Adaptive Resonance Theory (ART) Network

10) Real-Time Recurrent Network

11) Elman Network

12) Hopfield Network

13) Boltzmann Machine

14) Recirculation Network

15) Brain-State-In-A-Box (BSB)

16) Bi-Directional Associative Memory (BAM) Network

In general for selective harmonic elimination (SHEPWM) techniques different optimization methods are used to find the solution of a set of non-linear algebraic transcendental equations for generating switching angles in relation to modulation index (M).This leads to a large number of lookup tables with switching angles pertaining to different modulation indexes which are stored in advance to perform offline implementation of SHEPWM based converters for both (50/60 Hz time window). However, generating switching angles online for SHEPWM inverter is a real challenge for the researchers. In recent years new online techniques based on microcontroller, FPGA, microprocessor and DSP are used to implement SHEPWM for power converter. **Apart from above mentioned techniques neural network-based approach was implemented for real time SHEPWM problems. Feed forward artificial neural network (ANN) was one such technique used to generate the suitable switching angles such that the fundamental frequency component was kept constant and the low order harmonics were minimized or eliminated. To overcome the problems of ANN, GNN is proposed in this work.**

2.4.2Generalized Neural Network

The common neuron structure as shown in Fig.4b has summation as the aggregation function with sigmoidal, radial basis, tangent hyperbolic or linear limiters as the thresholding function. The aggregation operators used in the neurons are generally crisp. However, they overlook the fact that most of the processing in the neural networks is done with incomplete information at hand. Thus, a GNN model approach has been adopted that uses the fuzzy compensatory operators [52] that are partly sum and partly product to take into account the vagueness involved. Many investigations on generalized neural network (GNN) for various engineering and technological issues are documented in the literature [52]–[61].

2.4.3 Quantum Inspired Evolutionary Technique (QIET)

The principal limitation to optimized pulse width modulation technique, which selectively eliminates several lower order harmonics in the output voltage of the inverter, is in solving the non-linear equations which contains trigonometric terms, are transcendental in nature and therefore exhibit multiple solutions.

Recent advances in computation have stimulated the development of a family of techniques such as Evolutionary Strategies (ES), Genetic Algorithms (GA), Simulated Annealing (SA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Immune Algorithm, Tabu Search (TS) are the most popular stochastic search techniques as per the literature.

The major challenge for researchers with earlier algorithms was to establish a good balance between exploitation and exploration so as to overcome the limitations of slow and premature convergence. In [59, 62] the performance in terms of convergence speed and quality of the solutions was improved by the method of hybridization of Evolutionary Algorithms (EA) with other heuristics such as simulated annealing, local search, tabu search, hill climbing, dynamic programming, greedy random adaptive search procedure and quantum computing. In [60] has proposed a hybrid scheme which incorporates an Evolutionary Computational Technique (ECT) by combining GA and SA which overcomes the problem of local convergence and also the problem of multiple minima. In the population a two levels of competition was introduced between the strings so that only the better strings will continue in the population. To enhance the computational effort to search in the better regions of search space, the concept of acceptance Number was introduced.

2.4.4. Power quality issues

Power quality is the possibility of measuring and quantifying the performance of the power system and not related to the performance of equipment". Different organizations like the Institute of Electrical and Electronics Engineers (IEEE) dictionary, the definition in the International Electrotechnical Commission (IEC) standard IEC 61000-4-30 have given various definitions of power quality [89]. In [90] the "power quality issue" is defined as "any power problem manifested in voltage, current, or frequency deviations that results in failure or malfunction of customer equipment". Sometimes power quality problems may not show the effect immediately, for e.g. the harmonic distortion may increase the aging of electrical components; without causing any immediately failure or malfunction.

The differing influences of harmonics in power system networks can have serious long-term consequences, of which the most important ones are [79, 80]:

- Overloading of consumer's electrical installations and power system elements by higher order frequencies of currents and voltages;
- Increased heating of neutral conductors caused by triple current harmonics (frequency multiplier of number3). The increased level of the triple harmonics in the neutral conductor can cause serious damage and even leads to fires because the neutral conductor is not usually overload protected;
- Increased transformer heating caused by higher (order and magnitude) harmonics, as well as saturation effects in the core;
- Higher harmonics the power system can cause interference to telecommunication lines;
- Overstressing and resonant condition on the capacitors bank. For eg. A capacitor bank switching inside the MV circuit of a power plant can create impulses that can cause damage to other components on that circuit.

Power quality issues mentioned above have the potential to seriously impact plant economics, Optimization is really the key to success for any PV installation, but the formula for it will be different for each facility. The ability to use intelligent control solutions along with the technology is crucial in achieving an optimized system.

3. Proposed Work

In this work a real-time implementation of an innovative and integrated approach using soft computing techniques and Quantum computing technique is proposed for handling power quality issues in solar power.

3.1 Problem Statement

To develop an innovative and integrated approach using soft computing techniques and Quantum computing technique for enhancing the power quality of solar power system.

3.2 The objectives of the proposed work

The proposed work is divided as per the following objectives:

1. Study of power quality issues in solar power.
2. Development of an innovative and integrated approach for improving power quality.
3. Modeling and Simulation of solar power system along with proposed control technique
4. Real time implementation and verifying the results.

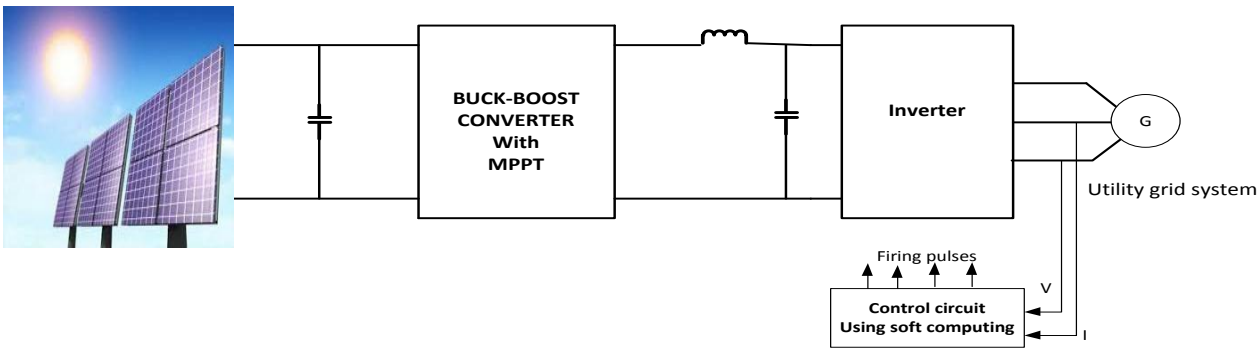

Fig-5: Proposed work

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